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Inland Resources Management

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SCIENTIFIC BASIS FOR THE CONSERVATION OF NON-OCEANIC LIVING AQUATIC RESOURCES

by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, 1968

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This paper was prepared for and submitted to the Inter-Governmental Conference of Experts on the Scientific Basis for the Rational Use and Conservation of the Resources of the Biosphere, Paris, 4-13 September 1968, convened and organized by Unesco, with the United Nations, the Food and Agriculture Organization and the World Health Organization participating, and with the cooperation of the International Union for Conservation of Nature and Natural Resources and of the International Biological Programme.

It was one of the eight basic review papers for Item 12 of the Agenda, The Rôle of Scientific Knowledge in Planning the Rational Use of the Resources of the Biosphere, and presented during Plenary Session. It was circulated by Unesco in advance of and at the Conference (in somewhat shorter form) as SC/BIOS/7, dated 12 July 1968.

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SCIENTIFIC BASIS FOR THE CONSERVATION OF NON-OCEANIC LIVING AQUATIC RESOURCES

Abstract

The paper is concerned with the application of scientific knowledge and experience to improve the production of the living inland aquatic resources (primarily fish) for man's use as food and recreation. It is also concerned with their maintenance as species for their intrinsic biological and educational value. It describes primary, intermediate and terminal production processes in non-oceanic aquatic environments, the utilization of inland aquatic resources, and the scientific basis (ecological, biological, economic, sociological) for their conservation.

The problems and prospects of scientific conservation are summarized with particular attention being drawn to the needs for: (1) better knowledge of aquatic resource biology; (2) the importance of harvesting and processing methods; (3) participation of aquatic biologists from the very early stages of planning and execution of land and water development projects; (4) cooperation of agencies as well as scientists and technicians concerned with resource management; and (5) an adequate number of qualified personnel with wide education in the major disciplines involved.

The adoption of positive policies and guidelines at national, regional and international levels is advocated.

1. INTRODUCTION

Even that fearless lexicographer, Dr. Samuel Johnson, has warned us that, "Definitions are hazardous". This is especially true for terms which, employed variously in different contexts and in different countries, have come to be used loosely. Thus, for the term "conservation", one finds in most dictionaries emphasis on the concepts of "protection", "preservation", "prevention of exploitation", and "keeping in a safe or entire state". Among modern biologists, however, a commonly accepted definition of the word is: "wise management and utilization of natural resources for the greatest good to the greatest number". We shall endeavour to follow this definition in this discussion. With respect then to living aquatic resources, "conservation" will include fishery management, i.e., the application of knowledge and experience to improve the production of fish for man's use; it will also with respect to these resources be concerned with their maintenance as species for their intrinsic, biological, and educational values. Living aquatic resources include, of course, various useful plants, invertebrates, and vertebrate animals other than fish; emphasis in this paper will, however, be on those fin fishes and shellfishes primarily utilized by man for food or sport.

For the purposes of this paper, non-oceanic aquatic resources are defined as the living resources of inland waters - water areas situated within land limits - that are used directly or indirectly by man. These waters may be fresh, brackish, or saline - depending on the nature of the substratum, catchment area, or connection with the open sea. Their biota is also affected by the influence of the sea; euryhaline species may live part of their life in the sea and part in inland waters. It is, therefore, not easy to separate production in the two different types of environments, especially when considering resources of diadromous species.

The history of man's use of non-oceanic aquatic resources is as old as man himself. Early man's exploitation was probably seldom at such level as to cause permanent damage to aquatic resources and was sometimes characterized by extremely wise regard, verging on veneration, for the bounties of nature and anxiety to perpetuate them. Many ancient practices are even today considered sound management procedures. Fish were propagated artificially in China as early as 2,000 B.C. The regulation of fishing for carps on their spawning grounds during new- and full-moon periods, which were observed to be periods of peaks of spawning, was enjoined by tradition in India as early as 246 B.C. The fishing restrictions voluntarily observed by tribal communities even today in the Naga and Khasi Hill areas of India compare favourably with measures imposed by the fishery agencies of modern communities. In Scotland, the capture of salmon during the closed season was punishable by death in 1411 A.D., and other fishing restrictions (generally with less severe penalties!) were in practice in many countries by the 16th century. Irrespective, however, of their appropriateness in some cases, most of these restrictions meant to conserve the resources were not based on sound knowledge of the biological factors that govern its maintenance. A scientific approach to the problem of aquatic resource conservation appears to have originated only in the late 19th century.

Efforts to study and manage the resource have followed more or less the same pattern in most countries. With the establishment of agencies responsible for management or conservation of inland fisheries, it came to be well recognized that the resources of inland waters were not inexhaustible and required as much attention from man as he devotes to the development and management of terrestrial resources. In spite of such recognition, there were still, unfortunately, few scientific data at hand to provide the essential guidelines for conservation, and however interesting they were to scientists, most faunistic or natural history studies were of limited use, by themselves, for resource management. Most agencies resorted therefore to the trial and error method - mostly error as Stroud (1963) points out - using so-called "self-evident facts".

This approach, as can be imagined, led to two major types of conservation activities: restrictions on fishing and fish-stocking operations. Fishing restrictions, often enacted without prior establishment of necessity and largely arbitrary in nature, failed in most cases to improve fishing. Furthermore, implementation of the restrictions was seldom easy, more so when convincing evidence could not be produced to show the public their usefulness. The more popular stocking operations came about as a result of the mistaken idea that the ill-effects of unwise use and management of the resource can be effectively countered simply by stocking artificially propagated young of indigenous species (or by the introduction of exotic species). They were often used simply as "political stocking" to promote goodwill. Again, such measures usually failed to improve fishing.

Today, we are in happier circumstances. Fishery biology and management have been formulated as a multi-disciplinary science and the need for detailed research and experimentation to evolve sound techniques of management has been recognized. Considerable advance has been made in this field: certain concepts and methods once considered sound are being discarded, some have been modified, and some completely new ones have been evolved. Answers to many problems of aquatic resource conservation are still lacking, but substantial progress can be achieved through application of those measures which are proved.

During the last decade a number of commendable attempts have been made to discuss the scientific basis and the status of knowledge of aquatic resource conservation through conferences or symposia. Among those worthy of special mention are the following: the IUCN/FAO Symposium on The Influence of Soil and Water Conservation on Natural Aquatic Resources at Athens, Greece (1958), the Conference on Estuaries at Jekyll Island, Georgia, U.S.A. (1964), the Symposium on Estuarine Fisheries at Atlantic City, U.S.A. (1964), the Symposium on Man-made Lakes held in London, U.K. (1965), the Reservoir Fishery Resources Symposium at Athens, Georgia, U.S.A. (1967), the FAO World Symposium on Warm-water Pond Fish Culture in Rome, Italy (1966), and the International Biological Programme Symposia on Primary Production in Aquatic Environments in Pallanza, Italy (1965), and The Biological Basis of Freshwater Fish Production in Reading, U.K. (1966). The papers presented at these symposia cover most of the principles relevant to the subject under discussion.

2. PRODUCTION PROCESSES IN AQUATIC ENVIRONMENTS

The harvest of fish or any other aquatic organism by man is the culmination of a complex series of activities of the plants and animals dwelling in the aquatic environment. It is therefore obvious that rational harvesting of an aquatic resource must be based on considerations that include an understanding of the biological processes and inter-dependence of these biota in the environment.

Production processes in aquatic environments are generally divided into three stages, viz., primary production, secondary or intermediate production, and tertiary or terminal production. Primary production is for all practical purposes equivalent to photosynthesis - a synthesis by green plants of complex organic matter from simple constituents. And, again, for all practical purposes, we may consider that the plants involved in primary production in an aquatic environment are algae. The next stage, termed secondary production, is the production of organisms that feed on green plants, but since it is difficult to separate these organisms from others that feed on detritus and bacteria, the more general term "intermediate production" is used (Ricker, 1968) to denote production of invertebrates, especially the smaller ones. The final stage is tertiary production which results in the production of fish or other animals that generally subsist on secondary or intermediate production. It has, however, to be emphasized that many fishes (or other animals included as constituents of tertiary production) may feed solely or partly on primary production. Many workers, therefore, prefer to use more specific terms like "fish production" denoting only a particular category of animals. "Terminal production" may be a more inclusive concept, defined as the production of organisms directly used by man (for example, in addition to fish, animals such as crayfish, frogs, turtles, crocodiles, and waterfowl).

A very significant feature of the production processes is that considerable decrease in total bulk occurs through successive stages, accompanied by increase in the size of the individual components. And from man's practical standpoint, aquatic food chains (or webs) are often too complex and inefficient. The efficiency of conversion of primary into secondary and terminal productions is frequently very low, and much of the food produced at one level may never pass on to the next but returns as detritus to the bottom of the food pyramid. Experience in pond fish culture has clearly demonstrated that the largest yields (harvest) can be obtained from herbivorous species. Carnivores are the most inefficient utilizers of organic production and therefore the least biologically suitable form of crop. In certain areas, however, for economic or sociological reasons their production may be highly desirable.

To maximize terminal production it may be necessary to manipulate the food chains or webs and maintain them in a desired pattern. A good knowledge of the influence of environmental conditions and methods of controlling them is essential for such a process. The latter involves control of both "natural" and "artificial" environments and will be discussed in later sections.

3. UTILIZATION OF AQUATIC RESOURCES

Uses of water. Of all our natural resources, water probably has the largest variety of uses, ranging from domestic consumption, the production of fish, agriculture, industrial use including hydroelectric power production, navigation, and the transport of unwanted wastes, to the use for sport, recreation, and amenity. Fish production which is one of the most important of these uses is also among those least consumptive of water. Furthermore, experience gained in a number of countries has shown that it is possible to combine successfully the production of fish with many other forms of water use.

Harvest from inland waters. Wholly reliable statistics of the total harvest from inland fish production are not available, but according to figures reported to the Food and Agriculture Organization of the United Nations (FAO), which largely represent marketable surplus from natural waters and exclude the very appreciable catches of subsistence and recreational fishermen, it is about 7 million metric tons annually. To this should be added the estimated production of 1 million tons from fish ponds (excluding Mainland China where the production by aquiculture is thought to be about 2.4 million tons). This is a substantial contribution to the world's supply of protein food, especially as most of it is eaten directly by man and much of it has high economic value.

Yet, despite the importance of the inland fisheries, the high level of interest in their development, and a noteworthy rise in production in some areas, no marked increase in the total world production of inland fish comparable to that for marine fish appears to have taken place during the last decade. This might lead one to believe that most natural inland fishery resources are being fairly well exploited; nevertheless, large areas still remain under-utilized, especially in some developing countries. And, although inland waters may appear to be more easily fished out, there are comparatively fewer instances of large inland fish stocks having been decimated solely by over-fishing than in marine waters. In most cases, the major factor contributing to lack of rapid expansion and, at worst, decreased yield, appears to be deterioration of the environment. And most such deterioration results from importunate or non-compromising demands upon the total aquatic resource and environment by conflicting uses of man.

Effects of changes in patterns of water-use. In early days, the utilization of aquatic resources - both living and non-living - was a relatively simple process. There was usually ample water for all uses and conflicts between varying uses were generally minor or of only local significance. But with the rise of industrial technology, urbanization, and population pressures, patterns of water use have changed appreciably and it has come to

be realized that the resources of inland waters are not inexhaustible and that exploitation of one type of resource can have very deleterious effect on others. 1/ In industrially advanced countries competing demands on water resources, reclamation of wet-lands and water pollution have had far reaching effects upon the aquatic environment, its consequent production and ultimately, therefore, upon utilization of this production. The same processes are now occurring in the developing countries, especially where the growth of agriculture and industry is being hastened by river basin development.

The construction of dams or barrages is usually a dominant feature of river basin development. Such structures and their operations may have the following effects on living aquatic resources. Dams often constitute barriers or deterrents to fish migration. They alter the magnitude, chronology and quality of stream flows below them and, therefore, may affect aquatic stocks by: reducing or increasing available space, and the size and quality of spawning, nursery and food-producing zones, and changing water velocity, temperature, chemistry, turbidity, and the river's ability for self purification. Diversions or conduits leading from dams often result in loss of fish which enter them and, in some cases, may result in the introduction of aquatic organisms into drainage basins to which they are not native.

The "flood fisheries" - fisheries in overflow areas of rivers during seasons of floods - contribute very appreciably to inland fish production in tropical countries, but as a result of flood control and irrigation projects such fisheries are fast disappearing. They have already almost disappeared in the industrialized temperate countries.

Pollution and reclamation also affect inland aquatic resources. Widespread use of insecticides and other pesticides as part of public health, agricultural and forestry practices is of special danger to aquatic life. For example, fish culture in rice fields is an age-old practice in many South-east Asian countries, which contributes substantially to much-needed protein production. But with the growing use of pesticides in rice fields, this form of aquatic production is fast becoming extinct. Large-scale reclamation of estuaries, lagoons and marshes for industry, agriculture, or real estate development has also destroyed valuable breeding and nursery grounds of fish and other aquatic animals.

Although many forms of land and water development have adversely affected fish production, others have created new and enlarged water areas for potential use in increasing fish production. Four of the major dams built in Africa alone in recent years, have created artificial lakes of a total area of about 19,000 km^2 (7,340 sq.m.). The Tennessee Valley Project (TVA) in the U.S.A. increased the water area of the Tennessee River system from about 45,600 ha (114,000 acres) to almost 240,000 ha (600,000 acres) and brought about a much greater production of fish than existed in the original rivers. Many more such reservoirs will be formed in the future and if properly managed, can yield considerable quantities of fish.

4. SCIENTIFIC BASIS FOR CONSERVATION

Conservation being the wise use of resources has necessarily to be based on scientific knowledge and experience. As the living aquatic resource, mainly fish, is biological in character, there is a natural tendency to consider only the biological basis for its conservation or management. Undoubtedly, an intimate knowledge of resource biology and the environment should form the basis of a conservation policy. However, realistic and practicable policies must also be based on judicious methods of harvesting, sound economics and suited sociological needs. For example, in the United States of America - where about 25

1/ The review by Dill and Kesteven (1960) has been used extensively in preparing this paper.

percent of the population already participates in fishing for recreation, spends almost 3 billion dollars annually for equipment and services for this fishing, and where the number of anglers is expected to increase 50 percent by 1975 and 150 percent by the year 2,000 - the adoption of conservation measures to preserve and increase the sport fish stocks (even while reducing certain competing "coarse fish" which are only of food value) has been judged to be the most appropriate policy for most inland waters.

Affluent societies - or at least certain segments thereof - exposed to comparatively less population pressures and having greater opportunities for leisure and recreation may like to preserve nature in its pristine purity for aesthetic reasons and scientific study; whereas an economically backward country faced with the problems of rapidly increasing population and inadequate food production will naturally have to design its conservation policy to meet the needs of improving food production, employment and well-being of its people. Undoubtedly the immediate needs should not be the sole basis of resource management and the long-term effects should be carefully considered and man's ethical responsibility to nature of which he is a part, be recognized. It is clear, therefore, that a uniform policy of conservation based on accepted biological principles alone cannot be recommended for adoption in all areas. An integrated scientific approach, based on all the disciplines involved is essential for the rational utilization and management of aquatic resources.

4.1 Ecological and Biological Basis

The biological basis of conservation is a sound knowledge of the biology and ecology of the resource.

As already stated, the "resource" or terminal production, mainly fish production, originates generally as a result of: (i) primary plant production, (ii) conversion of the organic matter produced by the plants into suitable food for fish, usually by a "food chain" of animals, and (iii) the feeding of fish and the conversion of the food into flesh. The fish produced is then harvested by man and the stock is replenished through reproduction (see Le Cren, 1958). Scientific management for optimum yield should be aimed at the control of all these stages as well as of the environmental conditions that affect them. Primary production should be maintained at the optimum level. The loss of organic matter involved in the conversion of food to fish should be reduced to the minimum. It should be ensured that mortality of fish due to natural causes and fishing is compensated by adequate reproduction and recruitment. Finally, as much of the production of fish as would permit the highest rate of sustainable yield should be harvested. Most of these phases of fish production are susceptible to human control in varying degrees. The control may be directed primarily at the environment, or it may be directed at the stocks themselves.

First, with respect to the physical environment, it is desirable that it be preserved in such condition that it can offer the following: (i) water in quantities adequate to provide sufficient "Lebensraum" and of suitable temperature and velocity; (ii) water of ample dissolved oxygen content and suitable chemical quality (including adequate quantities of nutrient salts and freedom from toxic or otherwise harmful substances); (iii) suitable substratum (for attachment, cover or shelter, spawning and hatching); (iv) freedom for movement and migration, etc. Given all such factors in the ideal environment there may still not be a full development of the resource in the manner that man desires it. Such development is also dependent upon the composition and relative densities of the biota and again man has an opportunity to control these. Finally, man's own predation (we call it fishing) upon the aquatic stocks is a factor of high importance.

It follows, therefore, that any discussion of the preservation or alteration of the non-oceanic environment and the conservation of its resources must consider man as a major component in an ecosystem which - either through design or inadvertence - he has already altered decidedly. To be quite realistic, in this shrinking world there are an ever-diminishing number of inland waters which one can call "natural" and many of these will

soon lose their original character. Can one call the regulated Columbia or the Danube or the great reservoirs on the Zambezi, the Volta and the Nile, or the polluted Rhine or the eutrophicated lake of Geneva or Lake Erie, or even small highland becks or alpine lakes whose trout, like the carps of the Ganges plain, contain measurable amounts of pesticides - can one call any of these "natural" today?

Thus, we come now to the main theme of our discussion: (i) how can we best conserve inland waters for aquatic resource production, and (ii) given such production, best manage it on a rational basis for the use of mankind. We may briefly outline below the major methods of preservation and management of these resources considered primarily from the biological basis.

4.11 Control of the physico-chemical features of the environment

Adequate water supply. Of primary importance is the provision of sufficient water in lakes, streams and reservoirs throughout the year. In completely natural lakes or streams, the supply of water is largely dependent upon the natural hydrological cycle, but obviously this cycle can be modified (as through reforestation) to bring about increased or improved water supply. In artificial waters or those affected by dams or other engineering works, the regulation of such dams, the inlets and outlets of reservoirs and the control of water levels are important elements of such water provision. Such regulation provides not only living space, but has profound effect upon food supply, movement and the success of spawning.

Water temperature. A major factor influencing all phases of production is water temperature. Even though this is part of the natural hydrological or seasonal cycle, man can modify it. The temperature of streams or lakes can be altered by provision or curtailment of shade or the deepening of pools. Selective release of water from surface or lower levels of reservoirs above dams can result in a supply of water of required temperature range in the downstream area. Use of the vast quantities of heated water from the cooling towers of thermal and power stations promises in some localities to be an effective means of raising temperature in otherwise temperate aquatic environments, resulting in higher biological production (but see also the next section). Destratification of lakes and reservoirs by mechanical means may also result in higher production under certain conditions.

Water quality and pollution. Provision of water of good chemical quality is paramount in maintaining optimum production at all levels. Definition of such quality is, however, dependent upon the particular resource considered. Thus, salmonoid fishes require water of high oxygen content; this is of lesser importance to most tropical fishes. In any event, among the criteria of greatest concern one must consider provision of water of adequate dissolved oxygen content, suitable range of pH and alkalinity, and freedom from excessive quantities of suspended solids, toxic substances, pathogenic organisms and contaminants producing objectionable tastes and odours. Obviously control of water pollution is essential in attaining such ends and one of the first steps towards these ends is the establishment of water quality criteria for the production of fish and other aquatic organisms. Within the developed countries, numerous committees or commissions, provincial and national governments and several inter-governmental bodies are now actively engaged in studying and recommending specific water quality requirements for all classes of water use including that for fish and aquatic life. This type of work - fundamental for aquatic resource management - should be extended throughout the world, preferably in advance of development.

Water pollution, which affects production in aquatic environment in all phases may be caused by domestic and industrial wastes, pesticides and herbicides, radioactive substances, oil, and other substances purposely discharged or inadvertently,(e.g., through air transit or land drainage) finding their way into lakes and streams. Of particular attention today to the aquatic biologist is the effect of the seemingly ubiquitous pesticides, eutrophication (or early aging) of waters caused by the introduction of excess nutrients, and the newest addition to the list of pollutants, heated (cooling) water discharged mainly from

power-generating steam plants, which can affect some cold-water species adversely.

With respect to aquatic stocks, the most serious effect of pollution is the slow degradation of the physical and biological environment, which usually goes undetected until well advanced, unlike mass mortality of fish and other aquatic organisms which is readily observed and thus attracts the most attention. When conservation agencies are able to work in close cooperation with industrial and city administration, suitable methods of pollution control such as pretreatment of effluents and regulation of effluent discharge, land disposal of pollutants and redesigning of processes to alter quality and quantity of effluents are possible.

Fertilization. Water must be "fertile", that is, contain nutrients, to produce an aquatic crop. There is, today, a considerable emphasis on wishing to decrease the fertility of certain natural waters - especially where excess nutrient supply has led to eutrophication, made them less attractive visually, and changed the composition of a fish stock from, say, a valuable coregonid population to a lesser one of cyprinids.

On the other hand, with many natural waters one may wish to increase fertility to obtain greater production. At present, efforts towards such fertilization seem best, that is, most economical, when directed toward small or controlled artificial ponds - those used for fish culture. However, the extent of control or influence possible is increasing with gains in scientific knowledge. Some experiments have demonstrated significant increase in photosynthetic rates following the addition of trace elements, and it seems possible that through use of such methods, economical means of fertilization for large water bodies can be evolved. Mention might also be made of the great store of nutrients in the hypolimnion of tropical lakes; there may be opportunity for bringing these back into circulation and thus increasing production.

Habitat protection and improvement. Many other management practices, generally termed habitat improvement, contribute to optimum production at all of its stages. Land treatment and water control measures, such as reforestation, cover cropping, terracing, contouring and drainage, prevent erosion and stabilize the soil. Excess turbidity that retards photosynthesis and thereby primary production is thus prevented, as also silting of stream riffles that result in smothering of plant beds and insects, and injuring spawning gravels. Careful preservation and improvement of watersheds is of vital importance in the conservation of inland aquatic resources, but often this type of management is beyond the means available to aquatic resource agencies and depends upon the general application of appropriate soil and forest conservation practices. Public education and coordination with other concerned agencies are essential to implement such measures.

In addition to such general practices, certain stream and lake "improvement devices" have been used for many years, on British trout waters, for example, and in North America where for a time they were heralded as the primary answer to providing good sport fish production. Some of these devices or methods (e.g., the use of deflectors to utilize the digging force of a stream to scour away silt from needed gravel, speed current and produce pools) have appeared to be useful. However, in many cases they have only short term value and may be unsound economically. On the other hand, small flow maintenance dams on natural lakes have provided unusual benefits through increased flow to provide sustained habitat in outlet streams - otherwise with no or meagre flow during the dry season.

Brush shelters in lakes are another means of "improvement". Many of these have been installed ostensibly as shelter for young fish and to provide substrata for periphytic food organisms. Their role in increasing tertiary (fish) production has not been well established, and in some cases they might better be called "attractors" in that they concentrate adult fish for easier capture. This may, of course, be advantageous in facilitating the overall utilization of the resource. They have traditional use for this purpose in the commercial and subsistence fisheries of some East European, Asian and West African waters, and are employed in recreational fisheries in the U.S.A. for certain centrarchids.

Provision of free and safe movement for fish. A highly specific form of stream improvement is provision of passage across or through obstruction. In some instances it may be advantageous to extend the range of a stock by the removal of natural barriers (such as waterfalls) or obstacles such as log jams on streams subjected to lumbering. In most cases, however, the problems lie in facilitating the passage upstream and downstream of diadromous fishes such as the Pacific salmon (Oncorhynchus), Atlantic salmon (Salmo salar) or the Indian shad (Hilsa) across man-made dams or weirs. The means adopted to ensure upstream passage are many: simple or complex fishways, fish lifts, fish locks, transport by trucks, etc. The selection of the method depends upon the nature of the dam and its operation, the biology of the species, and - because such devices are often very expensive - economic implications. As with the other problems of fish movement discussed below, ensurance of fish passage at dams is a very complex matter which requires close cooperation between fishery biologists and fishery engineers. (Its cursory treatment here must not blind the reader to this complexity.)

The passage of downstream migrants over dams has received adequate attention only in recent years. Although this may not be a very difficult problem at low dams with ample overflow, formidable difficulties are encountered in ensuring this at high dams forming large impoundments. As most young fishes migrate near the surface their passage over a dam may be possible if suitable spillways with regulated water flow and appropriate basal pools are provided. Other means of passage such as diversion tunnels or by-passes and even fishways may be used effectively for this purpose. A variety of methods, including artificial currents, lights, curtains of chain, walls of air bubbles, chemicals, vibrations, and electric shocking devices, have been employed to direct fish to use safe exits or reach collecting areas from where they can be removed by mechanical means. None of these measures has so far proved to be entirely satisfactory. Furthermore, no suitable methods appear to have been designed so far to ensure downstream movement of young or adult fish through large lacustrine areas of impounded waters. 1/ As more rivers become only a series of impoundments, the situation with respect to riverine migratory species becomes more serious, and demands intense study.

Heavy losses of fish, especially migratory species, may also occur when they enter diversions (canals, penstocks, etc.) from streams or reservoirs. Different basic types of fish screens such as stationary panel screens, parallel bar screens, rotary drum screens, belt-type travelling screens, perforated plate screens and louver systems, have been devised to prevent fish from entering such diversions. Electrical screens or deflectors which repel fish from entering diversions have also been used. They have the great advantage that they do not get clogged with debris as do mechanical screens. In any case, success of screens depends not only on correct design and placement, but on proper maintenance, and each installation demands individual study. Furthermore (and this has often been neglected) it has to be ensured that screens on diversions situated at some distance from the head-works are provided with by-passes so that fish can return to the streams.

4.12 Control of the biological features of the environment

Introduction of food organisms and forage fish. Many of the management techniques described above relate to the phases of production, including secondary or intermediate production. Introduction of food organisms or forage fish is adopted in waters where intermediate production is found to be inadequate. As many plankton-feeding fishes seem to feed by capturing individual plankton animals rather than by a straining process, the size of zooplankters and the density of their populations are of considerable significance. It is therefore possible that the introduction of larger planktonic crustaceans like phyllopods and mysids would contribute to greater fish production. In many waters the major food resources of fish are benthic invertebrates such as oligochaete worms, chironomid (midge)

1/ A paper by R.F. Raleigh and W.J. Ebel (in Lane) describes a method for ensuring downstream movement of young Pacific salmon through a large deep impoundment through timed drawdown.

larvae and small molluscs. Where the occurrence or densities of populations of these organisms have been found to be limiting factors, their introduction and facilitation of growth may be most desirable. The systematic planting of mysids and polychaete worms in reservoirs in the U.S.S.R. is reported to have resulted in spectacular increases in fish production. The introduction of pelagic forage fishes to occupy otherwise unused central or offshore water masses of reservoirs has also been accomplished with notable success, especially in certain waters where the carnivore population constitutes the desired harvest.

Control of aquatic vegetation. Although certain invertebrates and fishes make use of higher or vascular aquatic plants, plant growth is often harmful to aquatic resource production and harvest, and in some areas its excessive development is a major concern. Classic examples include the rapid spread of the introduced (from South America, originally) water hyacinth, Eichhornia, in the waters of several continents, and the introduction of Salvinia, an aquatic fern, to the newly impounded Lake Kariba. The standing crop of water hyacinth in East Pakistan alone, which has recently been estimated at over 25 million tons, goes largely unutilized and is positively harmful to fish production and other uses of water. Among the detrimental qualities of aquatic vegetation may be listed their storage of nutrients otherwise available for primary production by algae, creation of shade which reduces photosynthesis, increased water loss by transpiration and interference with fishing.

Control of such plants is usually accomplished mechanically and chemically. Biological methods of control (the use of fish, snails and insects, for example) have also been tried, but harvest and use of the plants, rather than destruction may, in the long run, prove to be the soundest method of all.

Control of predation and competition; population manipulation. Attempts by man to control animals which prey on fish have been made for many years. Thus kingfishers have been trapped and pike gigged on trout preserves, mergansers have been shot on salmon streams, cormorants and crocodiles killed in African lakes and swamps. The results of studies of predation are not always conclusive and the subject is somewhat controversial. Local situations and desired ends determine whether it should or can be practised successfully. For example, control of otherwise unutilized predators may undoubtedly be valuable in areas of intensive aquiculture or where their control leads to higher survival of fishes whose food supply and consequent growth is assured. On the other hand, there is evidence to show that excessive destruction of predators may result in overpopulation with consequent stunting of the prey species. Introduction of predators may even serve as an effective means of controlling dense populations of economically unimportant species.

It is, however, not the control of comparatively few predators, but large-scale control or complete elimination by chemicals of competitive populations of fish which has been perhaps the major advance in inland fishery management by which man can influence tertiary production. The first chemical to be used with marked success was rotenone, which had three great advantages: it killed fish easily, did not destroy their food supply, and its toxic effects wore off in a short time so that the waters could be restocked with desirable fish species. Rotenone and now a large number of newer chemicals or formulations have been widely used for "reclaiming" lakes, especially in the United States to improve sport fishing, for over 25 years. Originally used in already established lakes and reservoirs, the use of chemicals has been extended in attempts to eradicate entire fish populations from the headwaters of a stream system downstream to the site of a new reservoir. Such elimination enables the new reservoir and its upstream drainage to be stocked from the start with only those species considered desirable. (This practice when it has eliminated species native to a drainage basin, has in some instances brought strong criticism from those with large interest in the preservation of native stocks or natural communities).

Aside from the use of chemicals to improve sport fishing, it has been conclusively demonstrated that in certain small water bodies, production of fish for food can be increased many-fold by completely eliminating existing stocks of uneconomic species by chemical and other means, fertilizing and restocking with economic ones. In some lakes treated in this manner in the U.S.S.R., the standing crop of fish food organisms is reported to have increased 500 to 700 times and fish production 6 to 10 times.

The control of fish by chemicals occupies much attention today. Selective chemicals - those which will affect but one species - enable a high degree of population selection. Their development as well as those of partial control to regulate rather than totally eliminate populations are among the most promising tools of fishery management.

4.13 Artificial stocking

Many successful aquatic resource management measures relate mainly to the terminal stage of fish production. As emphasized earlier, scientific management of a fishery resource should be based on adequate knowledge of the populations involved, their biology and their environment. The replenishment of the populations should balance their reduction in density due to natural causes and fishing. It has to be ensured that a minimum number of spawners are available in the stock and that adequate number of young are recruited to the stock. As observed in many other animal populations, in fish also there appears to be some density-dependent factor that tends to regulate their number. Although there is only scanty data available to show the nature of relationship between the size of spawning populations and their progeny, it is clear that adequate recruitment for efficient growth and optimum production can be provided by a moderate number of spawners.

In view of the above and the favourable environmental conditions for subsistence and survival that are likely to prevail in well-managed waters, the addition or continuous stocking for maintenance of artificially propagated fish is generally wasteful. It has, however, to be pointed out that there are a good many special cases where the practice is useful. Stocking may be necessary, for example, to maintain a high fish production in waters adversely affected by environmental changes, such as those where the spawning grounds have been lost. With respect to anadromous salmonids, stocking of hatchery raised fish, especially at the migrant stage, has yielded good economic results. Other examples of useful stocking are: replenishment of fish in waters where the stock has been destroyed (by pollution for example), in reclaimed waters, in new reservoirs, and where the introduction of a different species or species combination is desired. 1/ The stocking of "catchable" fish for sport fishermen, i.e., liberation of fish of such size that they can be removed immediately by angling does not fall within any of these categories. Its success is dictated primarily by economic considerations and can flourish only under affluent conditions.

4.14 Fishing regulations

Proper regulation of fishing may be necessary to conserve stocks in large bodies of water and as mentioned earlier is one of the first techniques used for this purpose. Using appropriate techniques for estimating population abundance, its rate of change and growth, mortality and recruitment rates, it is possible to determine the relationship between catch from a stock to the amount of fishing and to the sizes of fish at first capture. Proper management of a natural fishery has to be based on such information. Regulatory measures should be established only when the need for them has been determined and the effect of such measures estimated and found practicable. Regulation aimed at changing the proportion of stock caught or the sizes of the fish caught can be achieved mainly by restricting:

1/ The dangers of indiscriminate introduction of exotic species are, of course, well recognized.

(i) the sizes or condition of fish that may be landed;

(ii) fishing areas and fishing seasons;

(iii) fishing methods;

(iv) total catch and effort.

The suitability of these regulatory measures will have undoubtedly to be judged against economic and sociological considerations. Where it is practicable to return captured undersized fish to the water alive and selective fishing for size groups is possible, size limitations can be very effective. The closure of areas to fishing and establishment of closed seasons can effectively reduce fishing mortality and also help to control the sizes of fish caught when there are areas and/or seasons of concentration of size groups (e.g., spawning and nursery grounds during and after breeding seasons). Restrictions on fishing methods gnerally take the form of prohibition of or limits on the use of damaging methods, gear and implements, or prescription of constructional details such as mesh size. Such restrictions are particularly warranted when increased fishing effort will affect recruitment but should not be made at the loss of efficiency and increased costs of operation. Destructive methods of fishing, such as the use of poisons and explosives may be - in fact generally are - prohibited. Regulation of mesh size has been very widely used with success, especially in marine fisheries and one of its major advantages is that it does not generally affect the cost of fishing. However, where the fishery bears on multi-species resources, there can be considerable difficulty in designing appropriate mesh regulations that will ensure adequate catch of smaller as well as larger species. Effective fishery management in most cases will have to include control of fishing mortality (the amount of fishing) by limitation of total catch and fishing effort. The allocation of catch and effort quotas for each stock presents many problems, especially in large river systems and lakes where the fishing rights are owned by more than one country. Even in the same country, quotas should be allocated on an overall basis or on the basis of individual fishing units taking into account the organizational, economic and political situations.

4.2 Economic and Sociological Basis

In the discussion above of the methods for management of aquatic resources largely based on biological knowledge, it has been indicated that economic considerations should be taken into full account to decide the ones to be adopted under a particular set of circumstances. Normally any administration will take into account the cost-benefit ratio before implementing any conservation measure. Many of the management techniques mentioned require considerable sums of money and trained personnel to implement. It is, therefore, most important that appropriate economic evaluations are made before conservation measures are recommended.

Many expensive management measures could probably be avoided if water- and land-use projects which are potentially harmful to living aquatic resources were not carried out. However, such projects may be urgently required and implemented in an area for economic or sociological reasons, unless it can be shown that the value of the aquatic resource greatly exceeds the values to be promoted by the project. For aesthetic reasons and for scientific study, it may be highly desirable to preserve an area in its natural or close-to-natural state, but in the face of economic and sociological needs it is not possible to retain all areas in that state. The most realistic, and therefore scientific, approach will be to take stock of the situation in its entirety and give adequate consideration to all aspects before formulating a policy of wise management to derive the maximum benefit for man.

The nature of use of a resource, as for example whether the fish produced is to be used for sport or for food, may make considerable difference in the evaluation of relative values. The value of a commercial fishery for food production is to be judged largely on the basis of the commercial soundness of the operations involved and possibly of the con-

tribution it makes to the nutrition of the people for whom alternative sources of protein are not available; the criteria to be used for evaluating a sport fishery may also have to include its recreational, touristic and in some cases public relations value. Many measures that are uneconomical in a commercial fishery may, therefore, be justified in a sport fishery.

Large-scale reclamation of estuarine and marsh areas now being undertaken in many parts of the world has caused much controversy and conflict of interests. Here again the most appropriate decision may have to be based also on proper economical evaluation and assessment of sociological needs. The costs of reclamation for agriculture and aquiculture are relatively easy to compare. But if an area is to be used (naturally) as nursery and feeding grounds of fish, the actual loss due to their destruction may not be easy to assess, even though it may be large. If reclamation is for human settlement in highly populated areas with no alternative possibilities, the only possible solution may be to work out ways and means of minimizing the deleterious effects on aquatic stocks by provision of at least minimum nursery grounds or by the adoption of aquiculture to compensate the loss of production.

5. PROBLEMS AND PROSPECTS OF SCIENTIFIC CONSERVATION

Considerable knowledge has accumulated to serve as a basis for action in aquatic resource management. Nevertheless, many management techniques once considered effective have not stood the test of field application through the years and have failed to demonstrate their technical or economic efficiency. Ideally, basic knowledge is obtained from research. On the basis of this research, experimental management projects may be undertaken and the results of these pilot studies should provide the guide for scientific conservation. Considering the long and intensive work required to achieve this, it has to be admitted that we are still in the very early stages of building a scientific basis for conservation. It is said that even the broadest outlines of life history information are not known for less than one-half of 1 percent of the world's known 25,000-odd species of fishes! Probably even less is known of their environmental needs. The fishery biologist is sometimes taken to task for his slowness in advancing this knowledge. However, fishery science is young and only a comparatively small number of "fishery biologists" are really doing fishery research. The time of many of them is occupied almost wholly in management or quasi-management, trouble-shooting, administration and other duties. It is clear that although such activities are useful and necessary much of the expenditure for these services is at the expense of acquisition of basic knowledge or pinciples having wide application to pressing problems.

It is also very clear that problems which are already complex are getting more so with increasing agricultural, industrial and urban development. Fishery or conservation agencies are not always able to produce the basic data required to adapt land- and water-development programmes to the needs of aquatic resource management. The biologist cannot be blamed for this. Most commonly it happens that there is extremely limited time available to conduct the studies necessary for intelligent recommendations. Before the effects of a project on resources can be determined, it is necessary to know in relatively complete detail the design and operation of the project, and therefore the resource agency can often begin its study of probable effects and formulate methods of resource protection only after the engineering studies are well advanced. Investigations such as pre-impoundment surveys, which involve inventories of resources and their composition, soil types and the extent of their distribution in the basin, especially in relation to the spawning grounds of fish, characteristics of the water area, including silt load, areas and rates of siltation, extent and volume of water available, water level regime and flushing rate, nutrient status, thermal and chemical stratification and history of fish production, are obviously time-consuming. To add to this are the major gaps in our knowledge of resource biology previously emphasized.

Even in those cases where enough basic knowledge is at hand to predict the effect of land- and water-development on the resource, and where the tools of management or alleviation of ill-effect of the development is known - it is imperative that the fishery biologist be associated with the project at a very early stage. For example, where construction of a dam may decidedly modify downstream flow, planning during the initial survey and design stages may result in provision of appropriate patterns of water release and operating schedules that are not detrimental to aquatic production in downstream areas. Similarly, the harmful effect of fluctuations in lake level above the dam can be minimized by integrated planning at the drawing board stage of the project. Fishways where found necessary can be incorporated into the design of a dam at an early stage; later on this becomes difficult, more expensive and often impossible. A major problem with respect to reservoir exploitation today - manifested especially in Africa where some of the new impoundments are virtually great inland seas with high potentiality for fish production - is clearance of the site of trees and brush, either wholly or partially, before filling to make areas for fish capture available. Early biological and economic evaluation of net benefit in individual cases must precede such clearing programmes to decide on the extent and type of clearance justified.

Such examples could be multiplied but it has already been emphasized in previous sections that the basic requirement for solutions to problems of water resource management is an integrated approach. It must be admitted that such an approach and adequately coordinated action of various agencies concerned is rare. There is a tendency for many aquatic biologists and conservationists to view irrigation, drainage or hydro-electric engineers with antagonism and suspicion, and vice-versa. This is not entirely due to the incompatibility of their callings or their respectively desired end points, but more because of their lack of understanding of all the problems involved, probably borne out of incomplete education on both sides. It is therefore extremely heartening to see, at least in some countries of the world, biologists with training in engineering and engineers with a knowledge of ecology. Aquatic resource management can benefit immensely by having more of such people in the field. The greater degree of coordination and compromise that is urgently required in water resource planning and management can then be expected to become feasible. The need for the association of economists and social scientists - also with an appreciation of ecology - in planning of programmes can also not be over-emphasized.

The discussion of knowledge of conservation workers of related subjects brings us to the consideration of one of the fundamental problems of resource management, viz., the lack of and need for adequate number of trained personnel at all levels. Although the situation in this respect has improved in the last two or three decades in some of the advanced countries, it remains a major problem in most developing and many developed countries. Research scientists with broad-based training and well-qualified management personnel are essential to design and implement effective resource conservation policies.

The many and complex problems of conservation can be solved only by integrated planning based on a sound and progressively scientific policy adopted by governments and inter-governmental agencies. Such an approach results only from a clear-cut mandate for multiple-use planning, and governmental policies should be oriented towards this. There is a great need to build public recognition of the importance of conserving aquatic resources and ensure its reflection in guiding policies and legislation safeguarding the protection, use and enhancement of aquatic resources as an integral part of water development.

Regional and inter-governmental bodies have played important roles in the development of other types of natural resources but unfortunately there are very few such bodies primarily concerned with non-oceanic aquatic resources. Regional and international cooperative action can do much to promote resource research as well as management of similar and especially of internationally owned resources. The formation of bodies dedicated to such action is desirable.

The foregoing discussion of the problems of aquatic resource conservation has endeavoured to draw particular attention to the need for: (i) better knowledge of resource biology, (ii) the participation of aquatic biologists from the very early stages of planning and execution of land- and water-development projects, (iii) a greater cooperation of agencies, as well as scientists and technicians concerned with resource management based on broader understanding of the problem, and (iv) an adequate number of qualified personnel with wider education, involving all the major disciplines concerned. Only if given these as a base, and with the adoption of positive policies and guidelines at national, regional and international levels - will it be possible to have appreciable and sustained advances in the conservation of the living resources of the inland waters of the biosphere.

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7. SELECTED REFERENCES

American Fisheries Society, 1966 — A symposium on estuarine fisheries. Spec.Publs Am.Fish.Soc., 3. 154 p. [Held at Atlantic City, U.S.A., 1964]

Dill, W.A. and G.L. Kesteven, 1960 — Methods of minimizing the deleterious effects of water- and land-use practices on aquatic resources. In IUCN/FAO (1960), pp. 271-307

FAO/UN, 1967 — The management of fishery resources. In The state of food and agriculture 1967. Rome, Food and Agriculture Organization of the United Nations, Ch. IV, pp. 119-44

Gerking, S.D. (Ed.), 1966 — The biological basis of freshwater fish production. A symposium sponsored by Sectional Committee on Productivity of Freshwater Communities of the International Biological Programme, The University, Reading, England, 1-6 September 1966. Oxford and Edinburgh, Blackwell Scientific Publications. 495 p.

Goldman, C.R. (Ed.), 1966 — Primary productivity in aquatic environments. Proceedings of an I.B.P. PF symposium, Pallanza, Italy, April 26 - May 1, 1965. Berkeley and Los Angeles, University of California Press, 464 p.

Hickling, C.F., 1961 — Tropical inland fisheries. London, Longmans. 287 p.

IUCN/FAO, 1960 — International Union for Conservation of Nature and Natural Resources, Seventh Technical Meeting, Athens, September 1958. Vol. IV. Soil and Water Conservation, Natural Aquatic Resources. 374 p.

Lane, C.E. (Ed.), (In Press) — Reservoir Fishery Resources Symposium. Presented by the Reservoir Committee of the Southern Division, American Fisheries Society, at the University of Georgia Center for Continuing Education, Athens. Athens, Georgia, University of Georgia Press.

Lauff, G.H. (Ed.), 1967 — Estuaries. Washington, D.C., Publs Am.Ass.Advmt Sci., 83. 757 p. [Proceedings of the Conference on Estuaries at Jekyll Island, Georgia, U.S.A., 1964]

Le Cren, E.D., 1958 The application of science to inland fisheries. A review of the biological basis of freshwater fisheries. FAO Fish.Study, 8. 52 p.

Lowe-McConnell, R.H. (Ed.), 1966 Man-made lakes (Proceedings of a symposium held at the Royal Geographical Society, London, on 30 September and 1 October 1965), Symposia of the Institute of Biology No.15. London, Academic Press. 218 p.

Pillay, T.V.R. (Ed.), 1967-68 Proceedings of the FAO World Symposium on Warm-water Pond Fish Culture, Rome, Italy, 18-25 May 1966. FAO Fish.Rep., (44) Vol.1 (1967: 55 p.), Vol.2 (1967: 174 p.), Vol.3 (1967: 423 p.), Vol.4 (1968: 492 p.), Vol.5 (1968: 411 p.)

Ricker, W.E. (Ed.), 1968 Methods for assessment of fish production in fresh waters. IBP Handbook No.3. Oxford and Edinburgh, Blackwell Scientific Publications. 313 p.

Rounsefell, G.A. and W.H. Evernart, 1953 Fishery science. Its methods and applications. New York, John Wiley and Sons, Inc. 444 p.

Schäperclaus, W., 1961 Lehrbuch der Teichwirtschaft, 2nd Ed. Berlin und Hamburg, Paul Parey, 582 p.

Stroud, R.H., 1963 Fish conservation. In The fisherman's encyclopedia, Rev.Ed. Harrisburg, Pa., The Stockpoole Co., pp. 329-413

Vibert, R. and K.F. Lagler, 1961 Pêches continentales. Biologie et aménagement. Paris, Dunod. 720 p.

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